

APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

**COUPLER ASSEMBLY FOR AN OPTICAL BACKPLANE SYSTEM**

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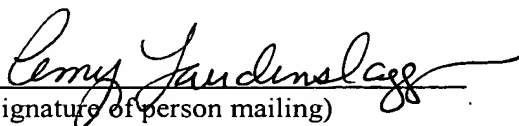
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## COUPLER ASSEMBLY FOR AN OPTICAL BACKPLANE SYSTEM

### BACKGROUND OF THE INVENTION

#### Field of the Invention

5           The present invention relates to optical circuits and, more specifically, to printed circuit board assemblies having optical circuit components.

#### Description of the Related Art

10           A modern telecommunications or computer system typically has a number of printed circuit boards (PCBs) or cards, which plug into a backplane or motherboard. The backplane generally provides power to the PCBs and a pathway by which the PCBs communicate with each other. For most backplanes, an electrical bus, which is typically a series of wires, is a primary means by which the communication between the PCBs takes place. Electrical transmission characteristics of the bus are defined by its material  
15           properties, the physical layout of the components, the clock speed of the signals, etc. As complexity of telecommunications and computer systems increases, signals within backplanes are driven at increased clock speeds. However, at relatively high clock speeds (e.g., over 1 GHz), the performance of electrical buses may become unsatisfactory due to dispersion, crosstalk, and emission of and susceptibility to electro-magnetic radiation.

20           To overcome this problem, backplane systems in which signals are transmitted through backplanes via both electrical and optical buses have been proposed. For example, one such backplane system is disclosed in U.S. Patent No. 6,005,991, the teachings of which are incorporated herein by reference. However, one problem with optical backplane systems is that relatively accurate alignment is required to properly  
25           couple light between the backplane and the PCBs plugged into that backplane. For example, an optical bus of the backplane has to be sufficiently well aligned with the corresponding optical pathways and/or optical devices of the PCBs to provide reliable operation when the system is subjected to mechanical vibrations and/or temperature-induced deformations. In addition, backplane and PCB manufacturing tolerances that are  
30           typically less stringent than the required backplane/PCB alignment precision have to be appropriately accommodated.

### SUMMARY OF THE INVENTION

Problems in the prior art are addressed, in accordance with the principles of the present invention, by a coupler assembly adapted to optically couple a circuit pack to a backplane in an optical backplane system, which can accommodate possible

5 misalignment between the circuit pack and the backplane and is adapted to correct (1) initial misalignment typically present when the circuit pack is first connected to the backplane and (2) without further intervention from an operator, subsequent misalignment typically caused by mechanical vibrations and/or temperature-induced deformations. To this end, the coupler assembly may employ a movable optical element

10 that can automatically track changes in the relative position of the backplane and the circuit pack to maintain good optical coupling. In one embodiment, the movable optical element is an array of MEMS mirrors, each mirror adapted to direct light between an optical transmitter or receiver of the circuit pack and a corresponding waveguide of the optical pipe in the backplane. In another embodiment, the movable optical element is an

15 array of flexible optical fibers, each coupled between an optical transmitter or receiver and a corresponding waveguide of the optical pipe. One end of each fiber is fixedly connected to the optical pipe and has an angled surface adapted to direct light between the fiber and waveguide. The other end of the fiber is fixedly connected to the optical transmitter/receiver such that the fiber flexibility permits relative orientation of the circuit

20 pack and the backplane to be perturbed without deterioration in the optical coupling.

### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a cross-sectional view of a backplane/circuit-pack assembly according to one embodiment of the present invention;

25 Figs. 2A-B show three-dimensional perspective views of a circuit pack and a coupler assembly that can be used in the backplane/circuit-pack assembly of Fig. 1 according to one embodiment of the present invention;

Fig. 3 shows a cross-sectional view of a backplane/circuit-pack assembly according to another embodiment of the present invention; and

30 Figs. 4A-C show three-dimensional perspective views a coupler assembly that can be used in the backplane/circuit-pack assembly of Fig. 3 according to one embodiment of the present invention.

### DETAILED DESCRIPTION

Reference herein to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment can be included in at least one embodiment of the invention. The  
5 appearances of the phrase “in one embodiment” in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments.

Fig. 1 shows a cross-sectional view of a backplane/circuit-pack assembly **100** according to one embodiment of the present invention. Assembly **100** has a backplane  
10 **102** having an optical pipe **104** adapted to transmit optical signals through the backplane. In one embodiment, backplane **102** is a printed circuit board having an integrated array of optical waveguides that forms optical pipe **104** similar to the optical waveguides described in an article by E. Griese, “A High-Performance Hybrid Electrical-Optical Interconnection Technology for High-Speed Electronic Systems,” published in IEEE  
15 Transactions on Advanced Packaging, 2001, Vol. 24, No. 3, p.375, the teachings of which are incorporated herein by reference.

Backplane **102** supports two circuit packs **112a-b**, each connected to the backplane using a corresponding connector **114**. Each circuit pack **112** has a PCB **118** with circuit elements **116**, wherein connector **114** provides power and electrical  
20 connections to the circuit elements and, depending on the implementation, may fix the circuit pack in place on backplane **102**. To transmit and receive optical signals through optical pipe **104**, each circuit pack **112** has a transceiver package **122** comprising an optical transceiver **124** and a coupler assembly **126**. Each transceiver **124** has (i) one or more optical transmitters adapted to convert electrical signals into the corresponding  
25 optical signals for transmission through backplane **102** and (ii) one or more optical receivers (e.g., photo-detectors) adapted to transform optical signals received via backplane **102** into the corresponding electrical signals. Each coupler assembly **126** is inserted into an opening in backplane **102** and serves to optically couple corresponding transceiver **124** to optical pipe **104**. For each optical transmitter of the corresponding  
30 transceiver **124**, coupler assembly **126** has a lens **132** and a movable mirror **134**. Similarly, for each optical receiver of that transceiver, coupler assembly **126** also has a lens **132** and a movable mirror **134**. Each lens **132** is adapted to either collimate light

emitted from transceiver **124** or focus light entering that transceiver. Similarly, each mirror **134** is adapted to either couple the collimated light into a corresponding waveguide of optical pipe **104** or direct light from a waveguide of the optical pipe through lens **132** to the corresponding receiver of transceiver **124**. In Fig. 1, transceiver packages **122a** and **122b** are illustratively shown as emitting and receiving light, respectively. One skilled in the art will appreciate that, using its different mirrors **134**, each transceiver package **122** may simultaneously transmit and receive optical signals.

When each circuit pack **112** is first mounted on backplane **102**, the tilt angle of each mirror **134** is adjusted to obtain efficient optical coupling of receivers and transmitters of corresponding transceiver **124** to the corresponding waveguides of optical pipe **104**. More specifically, using control signals from a mirror controller (not shown), each mirror **134** sweeps through a range of tilt angles until optical interconnection is established. Then, the tilt angle is fine-tuned to optimize that connection. After the initial alignment, each transceiver package **122** may be configured to monitor the interconnection quality and to dynamically adjust the tilt angles of mirrors **134** to correct for possible misalignment caused by mechanical vibrations and/or temperature variations. Advantageously, due to the use of movable mirrors **134** in transceiver packages **122**, circuit packs **112** are relatively easy to couple to optical pipe **104** of backplane **102**. In addition, good optical coupling can be dynamically maintained during operation of assembly **100**.

Figs. 2A-B illustrate a circuit pack **212** and a coupler assembly **226** that can be used for each circuit pack **112** and coupler assembly **126**, respectively, in backplane/circuit-pack assembly **100** according to one embodiment of the present invention. More specifically, Fig. 2A shows a three-dimensional perspective view of coupler assembly **226** in a process of being connected to circuit pack **212**, and Fig. 2B shows a three-dimensional exploded perspective view of that coupler assembly.

Referring to Fig. 2A, circuit pack **212** has a PCB **218** with a connector **214**, using which the circuit pack can be attached to a backplane (not shown). Connector **214** is similar to each connector **114** (Fig. 1) and provides power and electrical connections to the circuit elements of circuit pack **212**. Using an edge card connector **244** and alignment pins **246**, coupler assembly **226** is attached to a transceiver **224** mounted on PCB **218**. Connector pair **244** provides electrical power and control signals to coupler assembly

226, while pins 246 guide an optical fiber array 248 of the coupler assembly to properly mate with transceiver 224. At the end of array 248 facing movable mirrors 232, coupler assembly 226 has an array of lenses (not visible in Fig. 2A) inside housing 250 analogous to lenses 132 of each coupler assembly 126 (Fig. 1).

5 Referring to Fig. 2B, coupler assembly 226 has a MEMS chip 252 oriented at about 45-degree angle with respect to a ceramic base 256. In one embodiment, MEMS chip 252 has sixteen individually movable mirrors 232 arranged as illustratively shown in Fig. 2B. One skilled in the art will appreciate that a different MEMS chip having a different number of movable mirrors may similarly be used. Light enters and exits  
10 coupler assembly 226 through an optical window 258 in housing 250. For example, when circuit pack 212 is attached to backplane 102 (Fig. 1), light from optical pipe 104 enters coupler assembly 226 through window 258, reflects off a mirror 232, and is coupled into a corresponding optical fiber of array 248. Similarly, light emitted from an optical fiber of array 248 reflects off a mirror 232, exits coupler assembly 226 through  
15 window 258, and is coupled into optical pipe 104. A driver chip 254 provides driving voltages used in MEMS chip 252 to appropriately and individually tilt mirrors 232. A representative MEMS chip suitable for use in coupler assembly 226 is disclosed in U.S. Patent Application No. 10/261,089, filed on 9/30/2002 and entitled "Monolithic MEMS Devices for Optical Switches," the teachings of which are incorporated herein by  
20 reference.

Fig. 3 shows a cross-sectional view of a backplane/circuit pack assembly 300 according to another embodiment of the present invention. Assembly 300 is analogous to assembly 100 (Fig. 1) and has a backplane 302 having an optical pipe 304 adapted to transmit optical signals. In one embodiment, optical pipe 304 is an array of buried  
25 waveguides located at depth  $d$  from an outer surface of backplane 302. Backplane 302 supports two circuit packs 312a-b, which are similar to circuit packs 112a-b of assembly 100. More specifically, each circuit pack 312 has a PCB 318, circuit elements 316 mounted on the PCB, and a connector 314, which provides power and electrical connections to the circuit elements. To transmit and receive optical signals through  
30 optical pipe 304, each circuit pack 312 has an optical transceiver 324 similar to corresponding transceiver 124 of Fig. 1.

To couple transceiver 324 to optical pipe 304, backplane/circuit-pack 300 has a coupler assembly 322 comprising heads 326 and 328. Head 326 is displaced with respect to head 328 when a flexure 330 connecting said heads is deformed. Coupler assembly 322 has an array of optical fibers 332, each adapted to couple a waveguide of optical pipe 304 to transceiver 324. Fibers 332 are flexible and are bent when head 326 moves with respect to head 328. Each fiber 332 extends from an edge of assembly 322 by length  $d$ . The end of this extension has an angled surface oriented at about 45 degrees with respect to the fiber axis. A reflective layer (e.g., metal) deposited onto the angled surface forms a turning mirror, which couples light in and out of fiber 332 while changing the light propagation direction by about 90 degrees. When inserted into a slot in backplane 302, the angled fiber end lines up with a corresponding waveguide of optical pipe 304 as shown in Fig. 3. The other end of each fiber 332 can be mated, using alignment pins 346 that are similar to alignment pins 246 (Fig. 2), with transceiver 324.

Circuit pack 312 can be attached to backplane 302, for example, as follows. First, head 328 is fixedly attached to backplane 302 such that mirrors 334 of fibers 332 are aligned with the corresponding waveguides of optical pipe 304 to provide efficient light coupling between the fibers and waveguides. In one embodiment, head 328 is affixed to backplane 302 using one or more solder joints 350 as shown in Fig. 3. Second, alignment pins 346 of floating head 326 are partially inserted into the matching holes in the housing of transceiver 324. Then, flexure 330 is flexed to align connector 314 with the matching connector part (connector receptacle) on backplane 302. Finally, circuit pack 312 is pushed toward backplane 302 to fully insert alignment pins 346 into transceiver 324 and secure connector 314 in the connector receptacle to arrive at the assembly structure shown in Fig. 3. In backplane/circuit-pack assembly 300, flexure 330 will typically be in a deformed state to accommodate a typically present mismatch between the positions of (1) transceiver 324 and connector 314 in circuit pack 312 and (2) the matching elements of coupler assembly 322 and backplane 302. Advantageously, coupler assembly 322 allows circuit pack 312 to be mounted on backplane 302 in a relatively simple and straightforward fashion while providing efficient optical coupling.

Figs. 4A-C illustrate a coupler assembly 422 that can be used as coupler assembly 322 in assembly 300 according to one embodiment of the present invention. More specifically, Figs. 4A-B show two three-dimensional perspective views of coupler

assembly **422**, and Fig. 4C shows a three-dimensional perspective view of coupler assembly **422** mounted on a backplane **402**. A flexure **430** that connects heads **426** and **428** in assembly **422** is a serpentine spring that can accommodate lateral head displacements. Fibers **432** and alignment pins **446** in assembly **422** are similar to fibers  
5   **332** and alignment pins **346**, respectively, in assembly **322** (Fig. 3). Angled ends **434** of fibers **432** are visible in the view shown in Fig. 4B. A circuit pack similar to circuit pack **312** (Fig. 3) can be attached to coupler assembly **422** and backplane **402** shown in Fig. 4C by inserting alignment pins **446** of floating head **426** into the matching holes in the transceiver housing on that circuit pack, mating the circuit pack and backplane electrical  
10   connectors (not shown), and pushing the circuit pack toward backplane **402** to secure both optical and electrical connections.

While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Although the present invention was described in reference to optical pipes comprising  
15   optical waveguides, the invention may similarly be practiced with optical pipes implemented using free space optics. Various modifications of the described embodiments, as well as other embodiments of the invention, which are apparent to persons skilled in the art to which the invention pertains are deemed to lie within the principle and scope of the invention as expressed in the following claims.